

New Measurements of Lunar Soils Using Laser Diffraction and Isopropanol Show a Smaller Average Diameter Compared to Sieve Measurements

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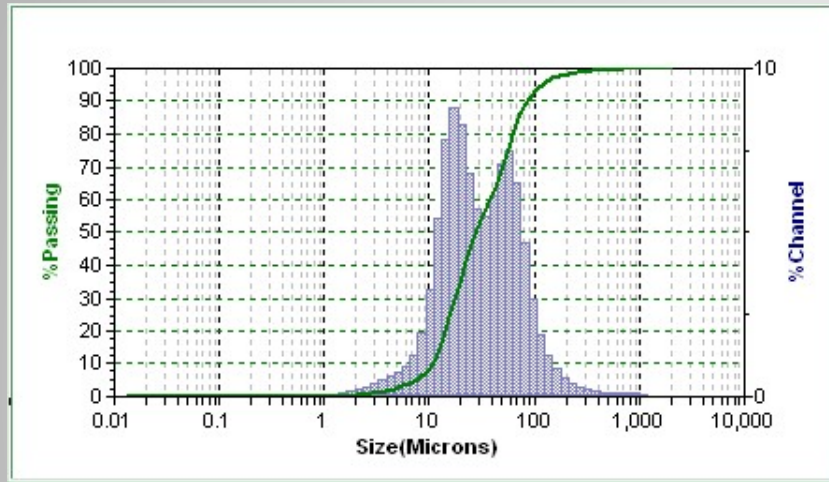
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Apollo 11 soil 10084

Many Techniques, Many Results

49.2



67.4

40.0

53.5

35.2

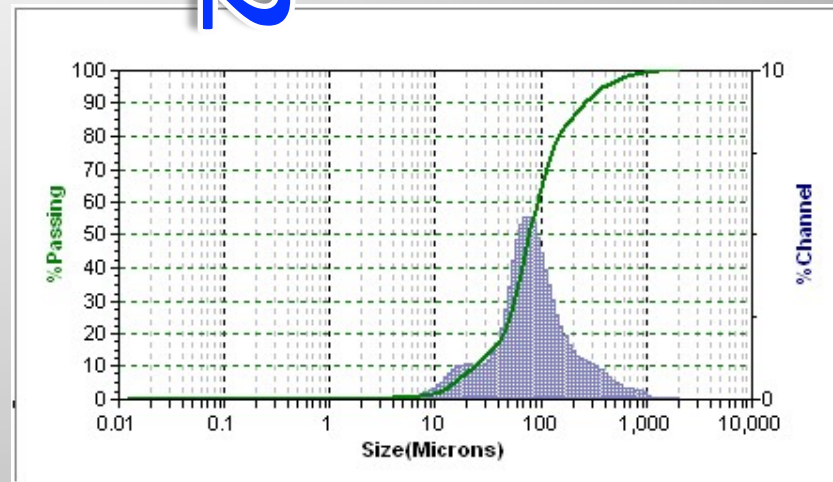
52.5

55.7

69.8

2.94

62.1

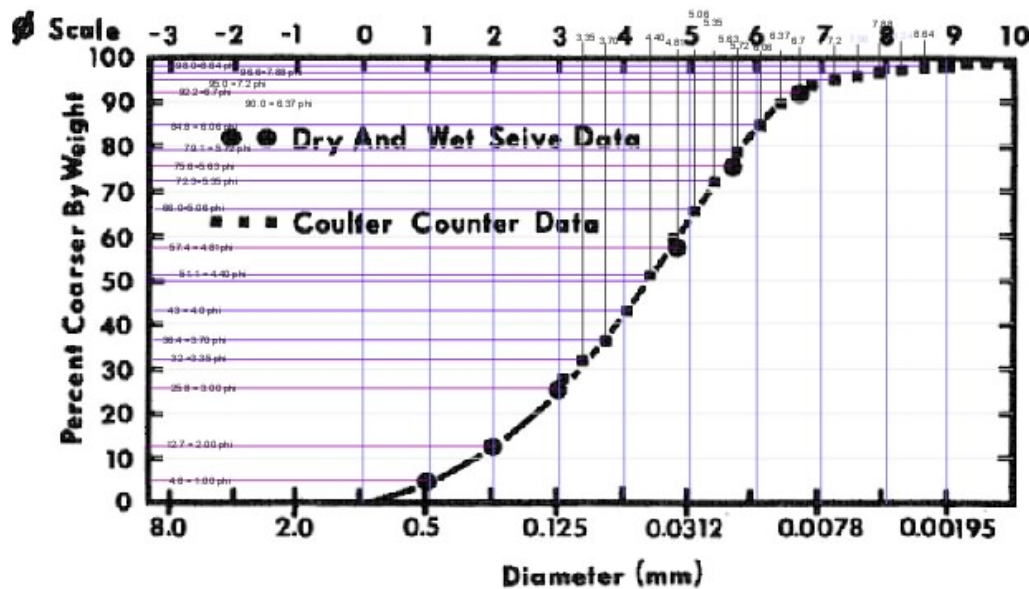
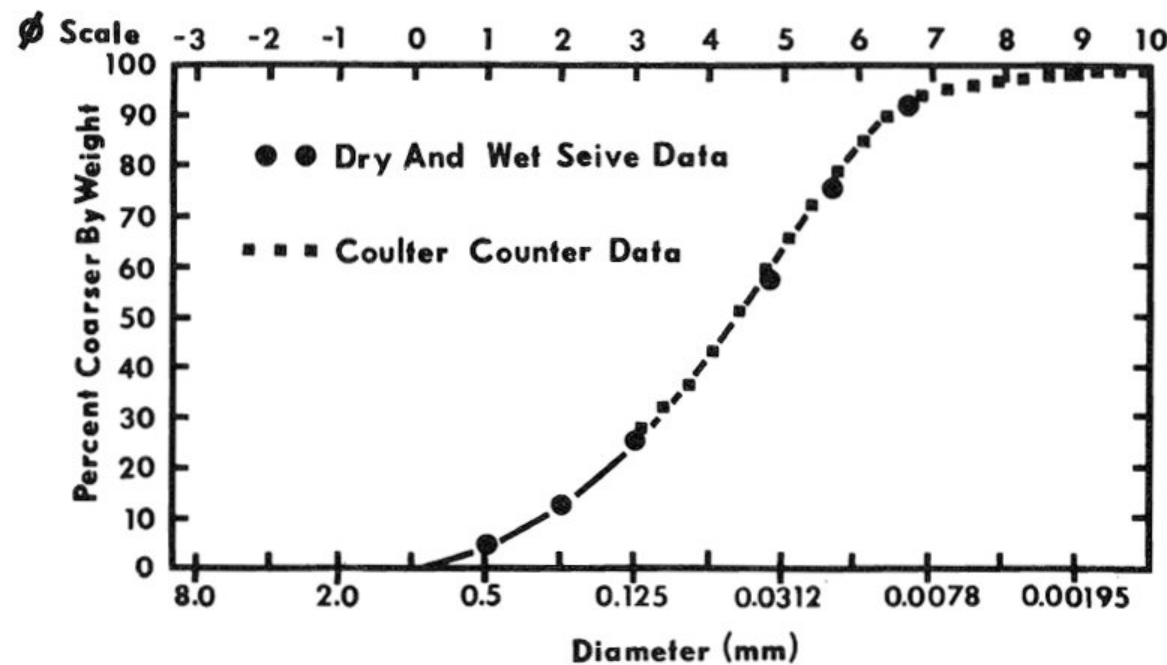


What's Happening?

- Dry Sieving: Fines Under-Reported:
 - Lost by airflow and by adhering to larger grains
- Wet Sieving: Fines Under-Reported and Bimodal Distributions:
 - Traditional fluids (Water and Freon) react with lunar soil, causing clumping, as well as dissolution of some material
- Laser Diffraction with Water Carrier Fluid:
 - same problems as with water for sieving—some particles dissolve, others agglomerate
- Laser Diffraction with Isopropanol:
 - No known issues

Duke et al. 1970

Both Duke & Graf adjusted the data to include the < 1 cm values provided by the Curator.
Duke: Median = 60 μ m
Graf: Gr. Mean = 85 μ m
Median = 61.6 μ m

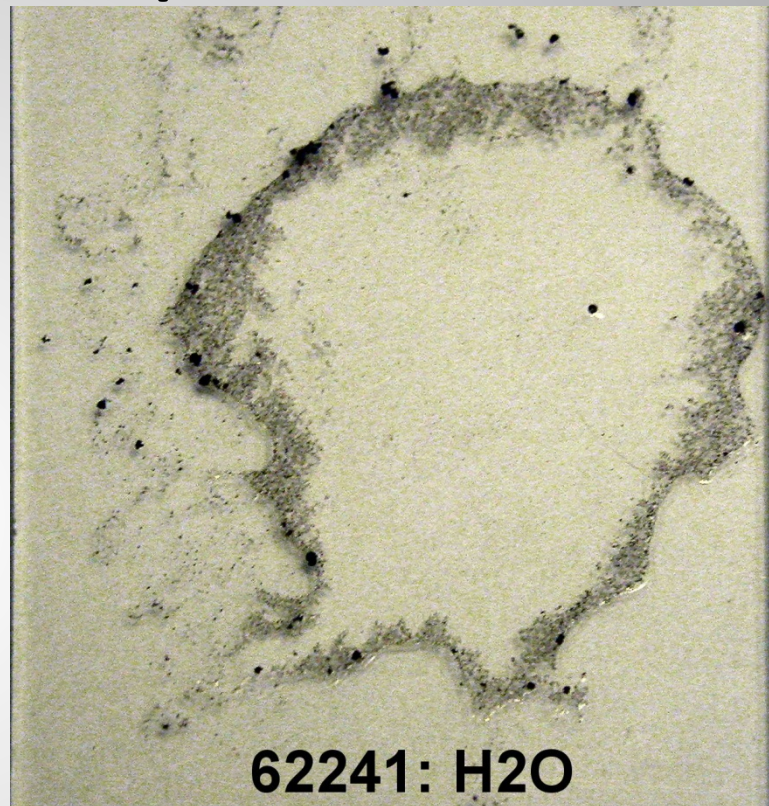


< 1 mm data was not presented. It is:
Graphic Mean = 53.4
Median = 49.7

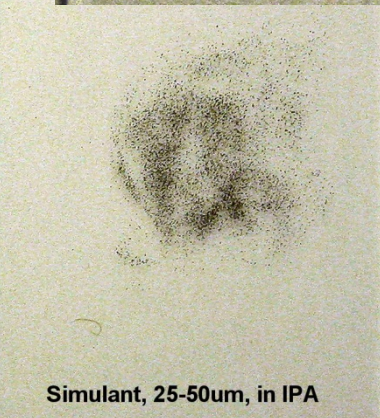
Lunar Soil Grains Clump in Water



62241: IPA



62241: H2O



Simulant, 25-50um, in IPA



Simulant, 25-50um, in H2O

Freon is Even Worse



A-14 Soils Placed in:

Freon

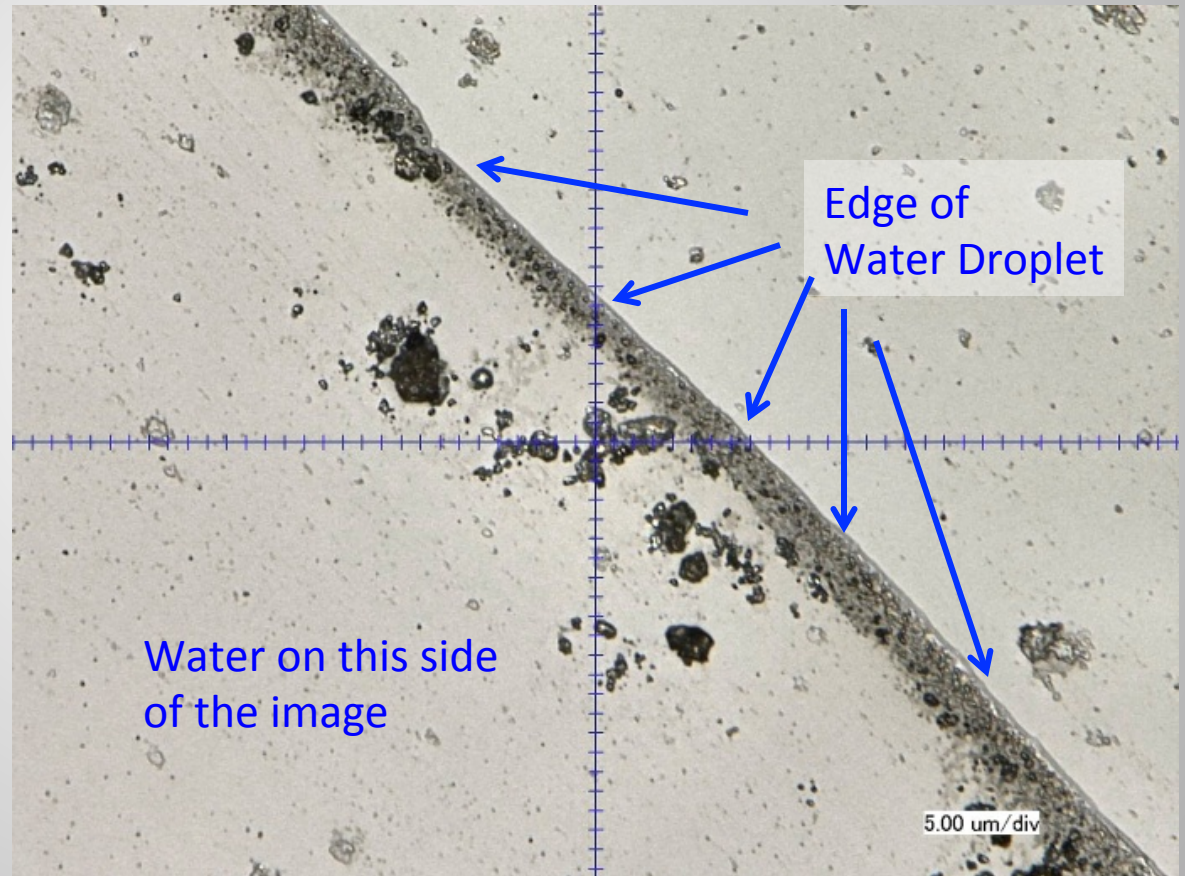
Isopropanol

Water

Serious Clumping



Jar after Freon Removed



Microscope image of A-14 soil in Water

Dissolution Study: H₂O vs. IPA

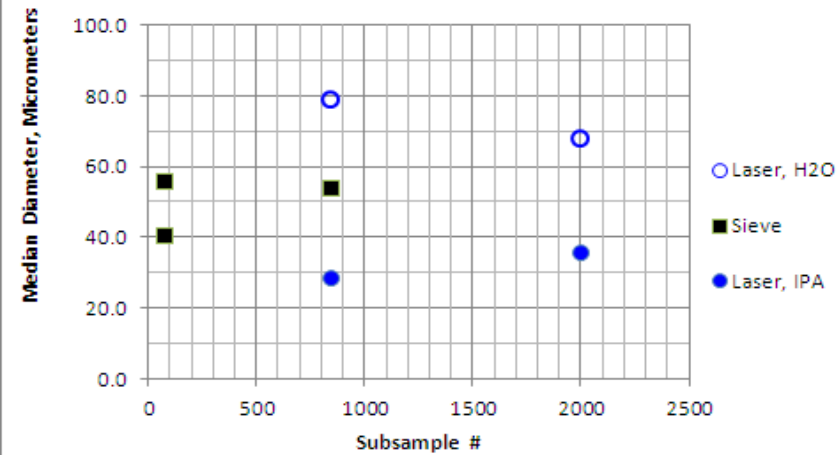
Element	Water Control (No Soil)	Lunar Soil in Water
Silicon	9	304.5
Calcium	0.14	0.53
Aluminum	2	3
Magnesium	0.04	0.32
Iron	8	5
Sulfur	0.7	0.7
Titanium	1	1

Major Metals Dissolve in
Water, but Not in
Isopropanol

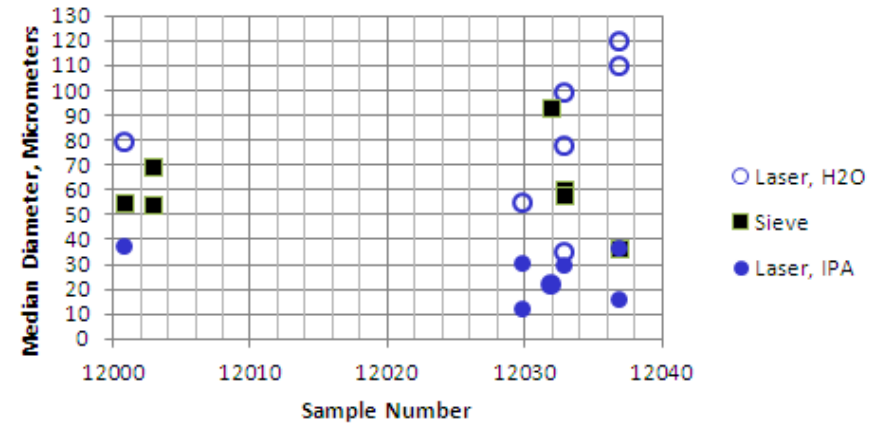
Element	Isopropanol Control (No Soil)	Lunar Soil in Isopropanol
Silicon	1500	1280
Calcium	0.2	0.1
Aluminum	8	8
Magnesium	0.04	0.04
Iron	20	20
Sulfur	1.6	1.6
Titanium	4	4

Comparison of Results

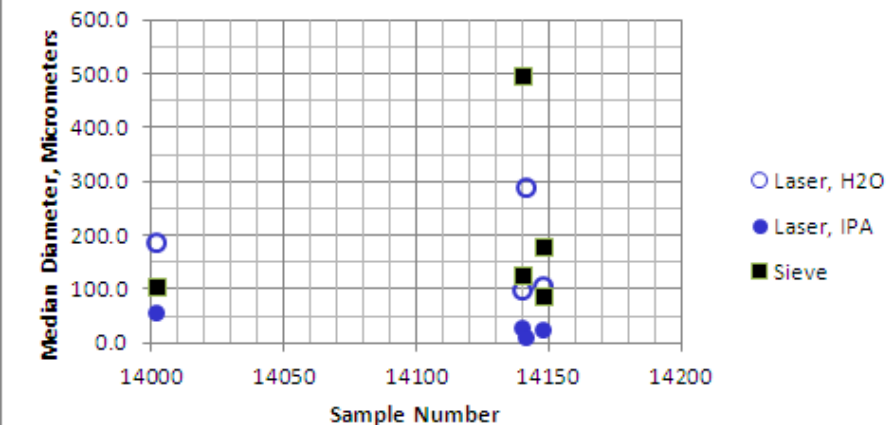
Apollo 11



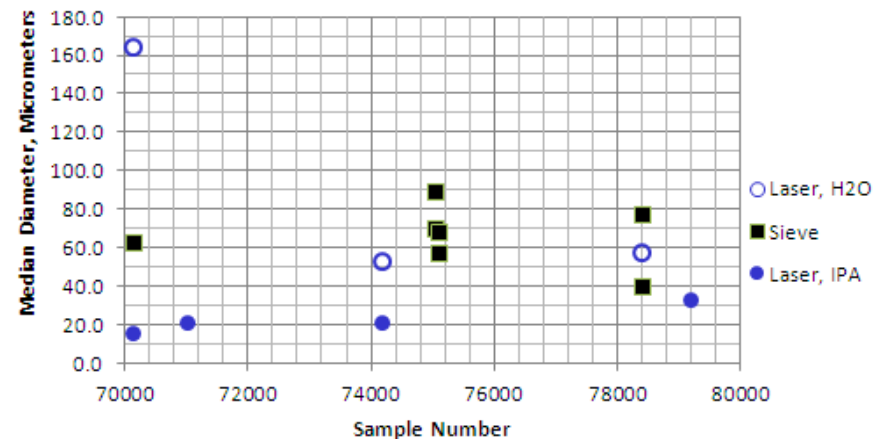
Apollo 12



Apollo 14



Apollo 17



Sieving = Loss of Finest Fraction

- When sample sizes are small, the problem with sieving gets WORSE.
- Demonstrated by the difference in results for samples measured by King (1971):
 - A **14-gram** subsample of 10084 produced a geometric mean of ~52 micrometers,
 - Two other subsamples of ~**1.5 grams** each resulted in means of ~63 and ~69 micrometers.
- Sample allocations for sieving are typically much smaller than a gram, and many of the sample allocations are only 0.25 grams.

Median is the Most Useful Value

- “The median ...is not affected by the extreme grains on either end of the distribution, and it is not necessary to have the complete analysis to determine it”. (Krumbein & Pettijohn, 1938)
- The median is least affected by differences in measurement technique or fluids used (Cooper et al., 2010).
- ***Median should always be reported.*** Mean or Graphic Mean may be included according to the preference of the writer.

Hapke was Right

“All other Apollo 11 samples listed in Table I... are...subsamples of one large sample.... The data from these investigators fall together in a band, except for the sample analyzed by **Hapke et al.** (1970), **which is significantly finer** than the others. *Because of this, the data from Hapke et al. have been neglected in the analysis that follows.*

LSPET. (1973) Lunar Soil Grain Size Distribution, [EARTH, MOON, AND PLANETS, V. 6, # 3-4](#), 250-263.

Summary

- We have re-measured 38 lunar soils with laser diffraction, using both water and isopropanol as a carrying fluid
- Laser diffraction with isopropanol is the preferred method for the present

Thank You

What is Happening: More Details

- Basu (2001): early sieve results on A-11 soil 10084 (e.g. [2, 3]) were misleading.
 - Sieving done on a clean bench with positive air pressure, or dry sieving with sonic sifters may deplete the finest fraction of the soil, producing particle size distributions that are skewed to the coarser end of the distribution.
- Sieving done with a fluid such as Freon or water causes clumping of the soil; and, in the case of water, it also dissolves a portion of the soil.
- The result is either a bimodal distribution or a distribution that appears much coarser than it really is, or both